

within the temperature-humidity groups. The temperature-humidity-wind types are further divided according to cloudiness, as indicated by shaded areas proportional to frequencies. Cloudy is indicated by black areas, clear by clear areas, and partly cloudy by crosshatching. Thus, since we find in the noon group of figures for July (reproduced as Figure 1) in the  $H_0$  column, and the  $T_0$  row a clear area covering 13 small squares under  $W_1$ , we see that 13 per cent of the cases at noon in July have temperature between  $60^\circ$  and  $74^\circ$  F., relative humidity between 50 and 74 per cent, clear sky, and wind velocity from 10 to 19 miles per hour.

If for any purpose it is desired to leave out of consideration any of the four meteorological elements used, the proper areas and percentages may be combined; this may be carried to the extent of eliminating all but any single desired element. In Figure 1 it is particularly easy to eliminate all but temperature and humidity by considering simply the percentage numbers on the face of the chart. Also, Table 1 is very convenient in combining and rearranging. We may readily rearrange our data so as to emphasize other elements than temperature and humidity. For instance, Dorno considers temperature and wind velocity more important in relation to human comfort (2); so in Figure 2 relative areas have been drawn for July noon data, using columns for wind velocity instead of for humidity, tabular percentage-frequency data having been properly rearranged accordingly. Of course, the details of the system may be modified, also, by changing the intervals used for any element, by substituting other elements for those employed, by the addition of other elements (such as intensity of radiation, atmospheric pressure, precipitation, etc.), and in other ways.

Thus, in his paper already mentioned, Dorno refers to the importance of considering departures of atmospheric temperature from that of the human body ( $36.5^\circ$  C.,  $96.6^\circ$  F.). Our temperature group  $T_{+3}$ ,  $96^\circ$  to  $105^\circ$  F.,

includes temperatures at and near that referred to. Other type groups may be thought of as being below or above the body temperature instead of being referred to zero of the usual scale.

If two days have the same sequence of weather types they may be said to have essentially the same weather. An examination of the regular thrice-daily observations taken at San Jose during July, 1926—apparently a month with fairly uniform weather—gave 28 different sequences for the 31 days. This illustrates the great complexity of the weather; any day is likely to differ from its neighbors, even when major features only are considered.

The principal purpose of this study is to show a method of indicating the atmospheric conditions that occur at a place. Having information in the form exemplified, it is possible for a person to tell with considerable accuracy how suitable a given climate would be for a given purpose, basing his conclusions upon his experiences with the various weather types elsewhere.

Furthermore, it should be possible to express numerically, and hence to appraise, the relative suitability of the different types for certain purposes. Thus, we might compute the rate of cooling of man under each type in accordance with the formula developed by Brooks and Donnelly (3) and (4).

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#### THE ST. LOUIS TORNADO OF SEPTEMBER 29, 1927

By MONTROSE W. HAYES, Meteorologist, U. S. Weather Bureau, St. Louis, Mo.

On September 29, 1927, at 1 p. m., a tornado moved across St. Louis, passed over the Mississippi River, and dissipated in Illinois, about  $3\frac{1}{2}$  miles from the river.

The weather map for 7 a. m., September 29, showed a barometric depression of considerable intensity over Nebraska and Kansas. Special observations at 1 p. m., the time of the occurrence of the storm, made in the Missouri and upper Mississippi Valleys, placed the center of the depression in western Iowa, exactly to the northwest of St. Louis, and 350 miles distant.

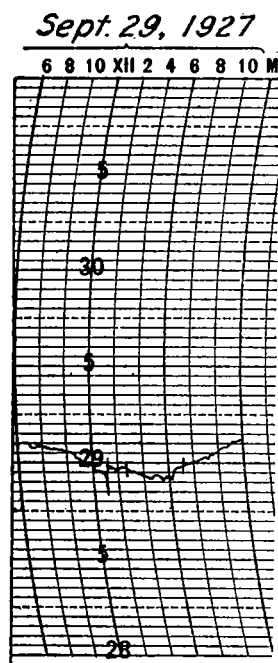
In St. Louis the day broke cloudy and rainy. Intermittent rain that began before daylight ended at 7:10 a. m. After the ending of the rain strato-cumulus clouds predominated, but during the forenoon the ceiling was broken and some alto-stratus clouds were visible. The sun shone for 25 minutes between 8 and 9 a. m. Shortly after 11 a. m. clouds became lower and thicker and rain began at 11:26 a. m. The rain was quite light for slightly more than an hour and a half. Low clouds were moving very rapidly from the southwest. At 12:41 p. m. lightning was seen and thunder was heard in the west. The thunderstorm rapidly overspread the west and southwest, and appeared to move to the northeast, its path being to the west of the Weather Bureau office. At 12:57 p. m. the clouds were very low, thick, and black. One large detached portion was particularly noticeable;

it seemed very little above the high buildings and from the Weather Bureau office it was west of and slightly to the south of the Bell Telephone Building. Although this detached cloud was quite black and angry looking no boiling motion was apparent. The rain became heavy, in a sudden downpour, at 1:02 p. m., and the wind had increased to a very high velocity by 1 p. m. The low clouds, and the rain driven by the high wind, made a solid impenetrable grayish-brown mass outside the office windows (looking to the south and west), and vision from the windows was totally obscured from 1:02 p. m. to about 1:05 p. m., when the atmosphere grew lighter. The wind force decreased materially at 1:05 p. m., but the rain continued heavy until 1:13 p. m. A special observation was begun at 1 p. m., but on account of the dark deluge of water through the instrument shelter the instruments could not be read; they were eventually read at 1:06 p. m.

The wind was strong from the southwest after 6 a. m.; at 12:35 p. m. it backed to the south, but occasionally veered to the southwest, and was not quite so strong. At 12:56 p. m. it came steadily from the south and increased in force. At 1:02 p. m. it veered to the west and blew from that direction until 1:06 p. m., at which time it became west-northwest. The maximum velocity was at the rate of 70 miles an hour in the five minutes

beginning at 12:58 p. m., and the direction was mostly south. The extreme velocity was at the rate of 96 miles an hour from the west, beginning at 1:02 p. m.

The barograph trace fell steadily until 10 a. m., when the rate of fall increased, and at about 12:50 p. m. the fall became much more pronounced. At 1:02 p. m. there was an instantaneous fall from 28.91 to 28.80, and the fall was followed immediately by an instantaneous rise to a reading of 29.02. The trace then fell steadily till 4 p. m., after which it remained almost stationary, with slight fluctuations, until 6:15 p. m., when a rise set in and prevailed through the night. A barometer reading made at 1:10 p. m. gave the following results: Actual reading corrected for temperature of the mercury, instrumental error and gravity, 28.833 inches; reduced to the station elevation (568.2 feet, or 148.6 feet lower than the barometer), 28.988 inches; reduced to sea level, 29.59 inches. Another reading, made at 2:20 p. m., gave corresponding results as follows: 28.805, 28.960, and 29.56 inches.



Barograph trace, St. Louis, Mo.,  
September 29, 1927

At the Weather Bureau office the storm was severe, but there was no general damage in the immediate vicinity. Some plate-glass windows were blown out, but the storm was not, at the time it occurred, considered more severe than heavy thunderstorms that occur from time to time. The Weather Bureau office is about  $1\frac{3}{4}$  miles from the nearest edge of the tornado, as indicated by minor damage, and is about 3 miles from the center of the path of the tornado, as indicated by the greatest destruction.

The storm apparently originated in the extreme southwest portion of St. Louis and moved in a northeast direction to the neighborhood of Tower Grove and Vandeventer Avenues, a distance of 4 miles. Thus far the path was about 300 feet wide and

the damage was in spots. There is considerable doubt about the progress of the tornado beyond Tower Grove and Vandeventer Avenues. It either bent northwestward or dissipated and another storm formed on Manchester Avenue, just to the west of Kingshighway, slightly more than one-half mile northwest of the path of the original storm. From Manchester and Kingshighway, across the extreme southeast corner of Forest Park, then northeastward to West Park and Taylor, a distance of three-fourths mile in a northeasterly direction, there was sporadic wreckage over a path about 300 feet wide. Then the path widened, the storm became violent, and the damage became general.

The fact that the original storm appears to have moved in a path parallel, near its terminus, to what may be called a second path, which had its origin near Manchester Avenue and Kingshighway, coupled with the observations of Dr. Clifford H. Farr, professor of botany, Washington University, would seem to indicate that it was a second and more violent formation that caused the great damage and loss of life. The notes of Doctor Farr's observations follow:

At 1 o'clock on September 29 I was waiting in the corridor on the second floor of Barnes Hospital, looking out of the north windows at the clouds. The impression which I gained by the increasing darkness was of an impending storm of some severity. I therefore stepped into a vacant room, No. 2422, in order to see the storm to the south. The window of the room was raised about 18 inches. It commanded a view south across Kingshighway (where it runs east and west) and into Forest Park in a direction parallel to the Taylor car line. The north and south stretch of Kingshighway and the car line were, however, not in view because of a wing of the hospital.

Upon entering the room I heard a sound as of an approaching train. Gusts of wind blew through the room. I went to the window to close it. As I did so the sound grew still louder, becoming a terrible roar. A dense dark cloud was resting in Forest Park. I could see across the street and some trees on the other side, but I felt that I could not see more than a block distant.

Then suddenly the scene changed. Out of this dark cloud there was organized a funnel. Judging its distance to be a block, I estimated its base resting on the ground as about 200 feet in diameter, its height about twice that of the hospital—that is, that of an eight-story building, and its diameter at the top as about 400 feet. After looking over the ground since the storm I have concluded that I visualized the funnel as nearer to me than it really was. Such a mistake would be easily made in an atmosphere of that foggy type. Now I think that the funnel when I first saw it was about three blocks away. In other words, I probably saw it just as it was toppling over the Bates statue. In this case the funnel must have been about 600 feet in diameter at the base and twice as wide at the top and perhaps 800 feet high.

Autos were running to and fro on the boulevard between me and the cloud. The trees along the street were being blown, but did not bend greatly. I marveled at so little disturbance of the trees. The funnel moved toward me; I thought directly toward me. As it approached I could see streaks in the cloud. Its outline was very sharp and clean-cut. Presently I saw boards and other objects coming out of the top of the funnel or near its upper margin. These must have come from the tennis courts which it crossed after leaving the statue. I felt that it was coming straight toward the hospital. The screen on the window was pulled loose by the suction. This distracted my attention from the funnel for a moment; and when I looked again the funnel was gone, I knew not whither. It must have then crossed Kingshighway to the Shriners' Hospital, which was not in sight from my window.

In place of the funnel, however, I saw the trees bending toward the east, before the most terrific wind that I have ever witnessed. The trees were almost horizontal; some of them were laid flat permanently. No cars were now being driven in the street. I expected to see the parked cars move, but I could not detect them doing so.

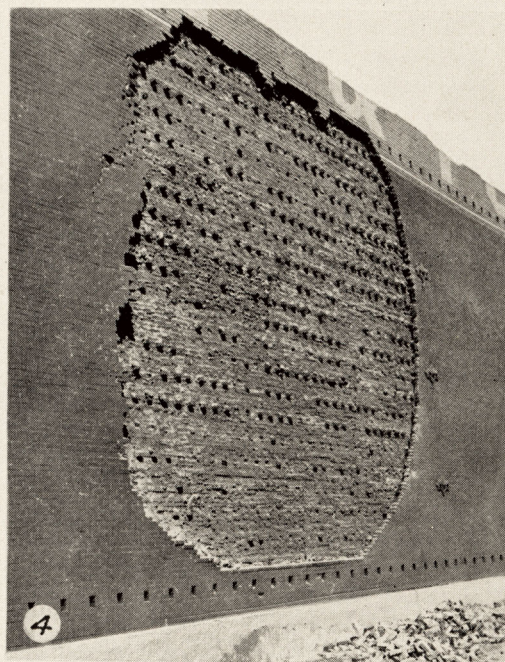
Almost immediately I heard windows in the hospital crash. One of these was a north window through which I had been looking in the corridor before I entered the room. It crashed in. Then the blow was over.

Evidently the funnel had passed to the east of us and the strong west wind which bent the trees and then broke the glass was blowing directly toward it.

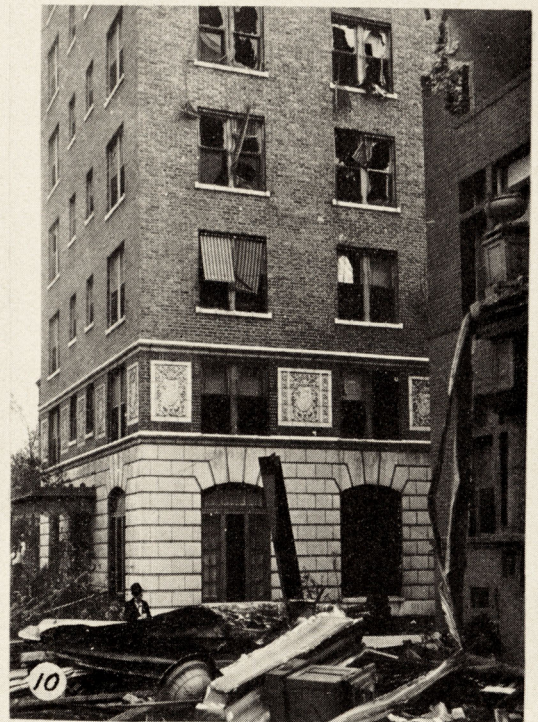
I have not made a careful study of the trees in the devastated area. However, casual observations while crossing it on Delmar, Lindell, and Pine make me think that the storm may have continued throughout its course much as I saw it. It appears that in an area about one and one-fourth blocks wide that the trees are not uprooted but are twisted off above ground and the tops and debris carried away. To the west of this area there is a zone of progressively less destruction for a distance of five or six blocks in which the trees are blown to the east, as if by a west wind, and the trees, branches, and debris are left in the street. To the east of the area the margin of progressively less destruction seems to be considerably narrower.

The path was almost due southwest to northeast from West Park and Taylor to the southeast limits of Granite City, Ill., where surface conditions of the whirling motion disappeared. There was general destruction over a path  $2\frac{1}{2}$  miles long and in places three-eighths mile wide, but scattered damage occurred in a zone somewhat more than  $1\frac{1}{4}$  miles across at its widest place, which was from Olive and Spring northwest to Easton and Newstead. At Grand and St. Louis Avenues the path narrowed considerably and the destructive action became much less general. Then on to the northeasterly end of the path,











in Illinois, the wreckage was not widespread. In fact, it seems that over this portion of the path the tornado's tube was not continuously in contact with the ground, but the winds, which were not markedly of a whirling nature, were excessively high. An interesting phase of the storm was the finding of papers in Hillsboro, Litchfield, and Mount Olive, Ill., that belonged to people in the devastated area of St. Louis. These towns are 40 to 50 miles northeast of a point just north of the McKinley Bridge across the Mississippi, where the storm crossed the river. The papers seemed to have dropped from the sky.

The time taken in the passage of the storm from southwestern St. Louis to the southeast of Granite City, in Illinois, is not known. All reports of first damage in St. Louis place the time "about 1 p. m." An instantaneous drop and rise in the barometer trace in the Weather Bureau office ( $1\frac{3}{4}$  miles southeast of the nearest edge of the storm, and 3 miles from the center) took place at 1.02 p. m., and the extreme wind velocity (96 miles an hour) was at the same time. Reports from the Illinois side of the river place the time of the storm "a few minutes after 1 p. m."

Where the storm crossed streets lined with trees it was quite easy to trace the center of the path by the direction in which the trees were lying. Some of the trees were twisted as much as  $90^\circ$  before being leveled. One plainly marked feature of the storm, and an interesting one, is the fact that the damage on the left, or west side of the storm's center, as indicated by the reversed direction in which trees were laid down, was confined to a very narrow strip, while on the right, or east side there was a broad swath of damage and destruction. In fact, there were many places in which the damage did not extend more than one or two hundred feet to the west of the first tree lying in a generally easterly direction.

A comparative analysis of the storm would be impossible, but judging from the reports of the character of destruction and from the pressure falls recorded by the nearest barographs, this tornado was not as violent in a meteorological sense as the St. Louis tornado of May 27, 1896, and the southern Illinois tornado of March 18, 1925. The instantaneous fall in pressure at St. Louis University, three-fourths of a mile southeast of the center of the path of the storm, was 0.20 inch. The fall was followed by an immediate rise to the former reading. At the Weather Bureau office, also southeast of the path, but 3 miles from the storm's center, the instantaneous fall was only 0.11 inch; however, the rise, which immediately followed, was 0.22 inch. In the Little Rock, Ark., tornado of October 2, 1894, the pressure fall was 0.37 inch and the following rise was to the original reading. The barograph in St. Louis on May 27, 1896, acted very much as it did on September 29, 1927; that is, it indicated a pressure fall of 0.22 inch, and the following rise was greater, being 0.40 inch. (The barograph was about three-fourths of a mile from the center of the storm.) On March 18, 1925, a tornado occurred in southern Illinois; it was one of the severest tornadoes of record.

A barograph trace said to have been made less than a mile from the outer edge of the storm showed an instantaneous fall, and a following rise, of 0.20 inch.

Destruction of life and property is obviously no criterion of the relative severity of storms. The path of the recent storm was through a section of the city consisting mainly, but not altogether, of rather old residences, flat buildings, and stores. The construction of these buildings can not be said to have been generally poor, although it was decidedly poor in some instances. However, the construction, as a rule, was by no means what it should have been, and the fact that at least two modern apartment buildings were damaged no more than was to be expected seems to bear out this assertion. There is considerable discussion and criticism of the mortar used in the damaged and razed buildings. Other phases of construction are also being discussed and criticized to some extent, and the entire matter may result in changes in building practices. The apartment buildings mentioned had windows blown out and some parapet walls blown off. In most of the damaged buildings near the storm's center the explosive effect was plainly marked.

In St. Louis 72 people were killed; of this number several died of injuries some days or weeks after the storm. The injured numbered around 500. Fortunately there were few fires following the storm. In Illinois seven people were killed and one man died of heart failure; there were about 50 injured.

The monetary damage is, of course, not definitely known, and probably never will be. A careful survey in St. Louis indicates that, exclusive of motor cars and the contents of buildings of whatever nature, the damage amounted to \$22,000,000. In Illinois the total damage probably was less than \$3,000,000.

NOTE.—The following legends, as well as the photographs here reproduced, were made and furnished by H. J. Woods, engineer of the Missouri Inspection Bureau:

FIG. 1.—Typical destruction of residence 4017 Enright Avenue

FIG. 2.—Columbia School (public), 2742 North Garrison Avenue. Walls blown out, particularly at southwest and southeast corners; roof practically destroyed. In some instances the brickwork between the windows only the face brick remained

FIG. 3.—Bucks Stove & Range Co., east side Second Street, between Destrahan and Mallinckrodt Streets. Heavy damage occurred on upper floors of the four and five story buildings. Buildings suffered in breakage of windows and one from falling stacks

FIG. 4.—Polar Wave Ice & Fuel Co., 4428 Duncan Avenue. Ice-storage house, having 4-inch dead air space in walls, vented at top and bottom of wall, as shown in photograph. Four-inch brick outer wall forced out by air pressure during storm. Greater destruction to other parts of plant; several men killed

FIG. 5.—Three residences completely destroyed—4106, 4112, and 4114 Enright Avenue

FIG. 6.—Examples of recent construction of small apartments using hollow tile with brick facing. Doubtless conditions could have been greatly improved by proper bonding of these walls and by the use of cement mortar

FIG. 7.—Showing destruction of facing over flues due to sudden drop in barometric pressure during tornado

FIG. 8.—Looking north from alley between Olive Street and Washington Boulevard. View of the rear of residences in the 4100 block on Washington Boulevard

FIG. 9.—View of the north side of 4100 block of Washington Boulevard. NOTE.—One structure shows second floor completely wiped out and third floor of mansard construction occupying former position of second floor, front room

FIGS. 10, 11.—Leonardo Fireproof Apartments, 4166 Lindell Boulevard. Part of west side shown in above photograph; entire window, including casing, on first floor, pushed out; damage to windows above. Rear view shows damage to parapet and to windows

FIG. 12.—Four O Six Six Fireproof Apartments, 4066 Lindell Boulevard. This apartment nearing completion; windows not all installed

## METEOROLOGICAL CONDITIONS OVER THE SEA IN THE EASTERN MEDITERRANEAN

By H. MEREDITH, B. Sc.

The observations referred to in the following article were made on October 14, 15, and 16, 1926, during a voyage in the Mediterranean Sea between Alexandria and Malta, and consist of measurements of the sea-surface temperature, the air temperature, and relative humidity at 21 feet above the water level, together with

the air-temperature gradient between the heights of 13 feet and 71 feet above the sea level. The observations were taken approximately at two-hour intervals throughout the voyage. Alexandria was left at about 1400 on October 13 and Malta was reached at 1000 October 16, the ship steaming a steady 12 knots throughout. The